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Grant County, Washington

National Eutrophication Survey, Las Vegas, Nev

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ON
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GRANT COUNTY
WASHINGTON
EPA REGION X
WORKING PAPER NO. 872

WITH THE COOPERATION OF THE
WASHINGTON DEPARTMENT OF ECOLOGY
AND THE
WASHINGTON NATIONAL GUARD
JULY, 1977

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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT ON MOSES LAKE
GRANT COUNTY, WASHINGTON
EPA REGION X

by

National Eutrophication Survey

Water and Land Quality Branch
Monitoring Operations Division
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Special Studies Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

Working Paper No. 872

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

July 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

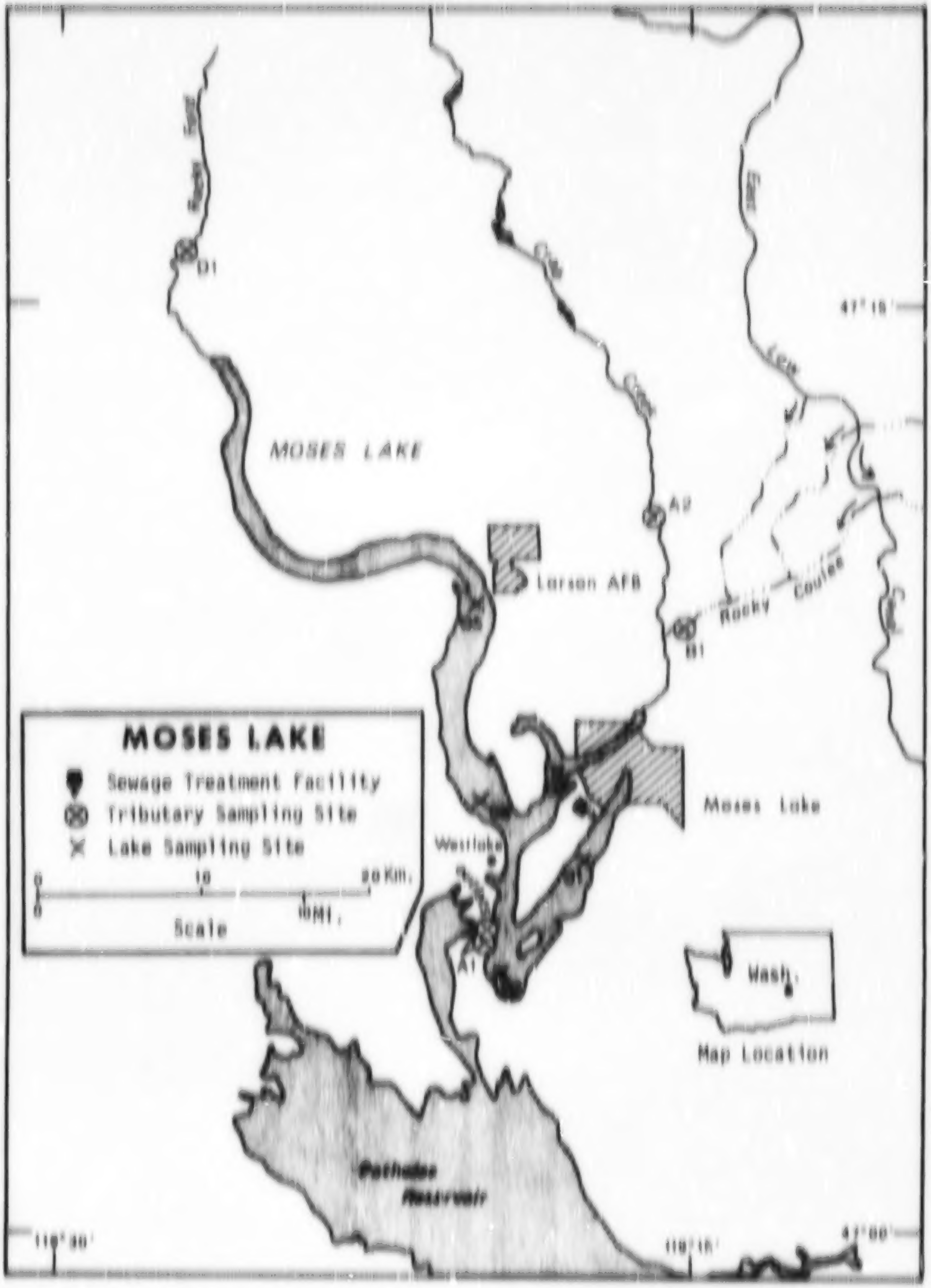
The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Washington Department of Ecology for professional involvement, to the Washington National Guard for conducting the tributary sampling phase of the Survey, and to those Washington wastewater treatment plant operators who provided effluent samples and flow data.

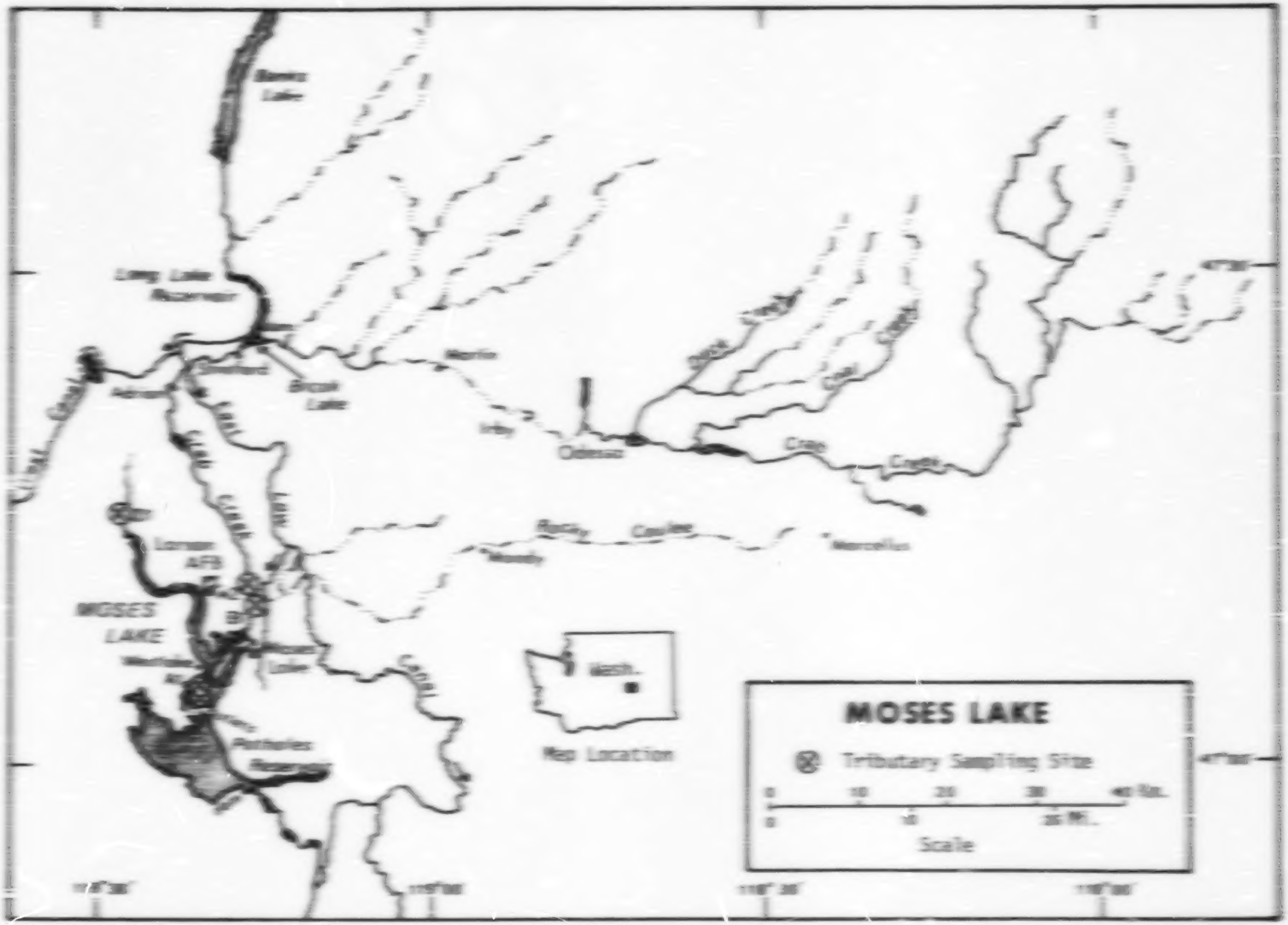
Ms. Barbara Blau, Lake Restoration Program, and the staff of the Washington Department of Ecology, Lake Restoration Program, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

Major General Howard S. McGee, Adjutant General of Washington, and Project Officer Colonel Clinton C. Johnson, who directed the volunteer efforts of the Washington National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY
STUDY LAKES
STATE OF WASHINGTON

LAKE NAME	COUNTY
American Lake	Pierce
Banks Lake	Grant, Douglas
Chelan Lake	Chelan
Diamond Lake	Pend Oreille
Green Lake	King
Keechelus Lake	Kittitas
Mayfield Lake	Lewis
Medical Lake	Spokane
Moses Lake	Grant
Ozette Lake	Clallam
Sammamish Lake	King
Lake Whatcom	Whatcom
Lower Granite Reservoir	Garfield, Whatcom


MOSES LAKE
Larson AFB
A2
B1
D1
A1
Rocky Coulee
Crab Creek
Moses Lake
Wheeler
47°15'
47°00'
119°30'
119°15'
MOSES LAKE
Sewage Treatment Facility
Tributary Sampling Site
Lake Sampling Site
0
10
20 Km.
0
10 Mi.
Scale
Wash.
Map Location
Potholes Reservoir


MOSES LAKE
Tributary Sampling Site
0 10 20 30 40 Km.
0 10 20 Mi.
Scale
Wash.
Map Location
Banks Lake
Long Lake Reservoir
Stratford
Brook Lake
Marlin
Adrian
Irby
Odessa
Crab Creek
Coal Creek
Creek
Canal
Rocky Coulee
Marcellus
Larson AFB
MOSES LAKE
Moses Lake
Potholes Reservoir
119°30'
119°00'
118°30'
118°00'
47°30'
47°00'

REPORT ON MOSES LAKE, WASHINGTON

STORET NO. 5309

I. CONCLUSIONS

A. Trophic Condition:*

Survey data indicate that Moses lake is eutrophic, i.e., nutrient rich and highly productive. Whether such nutrient enrichment is to be considered beneficial or deleterious is determined by its actual or potential impact upon designated beneficial water uses of the lake.

Chlorophyll *a* values in the lake ranged from 1.6 µg/l in April to 84.6 µg/l in September, with a mean of 29.1 µg/l. Lake water transparency was low and potential for primary production as measured by algal assay control yield was high in both spring and fall. Severe hypolimnetic oxygen depression was observed at several stations in the lake during July and September samplings. Of the 13 Washington lakes sampled in 1975, only 1 had higher median total phosphorus levels (0.115 mg/l), 3 had higher median inorganic nitrogen levels (0.150 mg/l) and 1 had higher median orthophosphorus levels (0.038 mg/l) than Moses Lake.

Survey limnologists reported algal blooms during July and October sampling. Other sources (Dion, N.P., 1976; Ketelle and Uttormark, 1971) report that this historically eutrophic lake receives heavy recreational use and nuisance blue-green algae blooms throughout the summer.

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*See Appendix E.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Moses Lake was limited by available nitrogen in the eastern arm during both spring and fall sampling, and phosphorus- or colimited in the western arms of the lake at those times. The lake data suggest primary limitation by nitrogen throughout the lake on all three sampling occasions except at Stations 03-05 in the spring, where phosphorus limitation is suggested.

C. Nutrient Controllability:

1. Point sources -

During the sampling year, the city of Moses Lake contributed 31.8% of the total phosphorus load to Moses Lake from a single sewage treatment plant. Exceedingly high phosphorus levels at lake Stations 01 and 02 reflect the discharges from the plant in the northeastern arm of the lake.

The calculated annual phosphorus loading of 1.13 g P/m^2/yr is more than twice that proposed by Vollenweider (1975) as "eutrophic" for a lake with such volume and hydraulic retention time (289 days). Elimination of the Moses Lake sewage treatment plant discharges would be expected to effect some water quality improvement in the lake; however, further reduction in nutrient loadings, including nonpoint, would be necessary to reduce the annual phosphorus loading to below Vollenweider's "eutrophic" level.

In March 1977, the Moses Lake Irrigation and Rehabilitation District began periodically diverting water from the Columbia River into Parker Horn (Welch and Lindell, 1977). It has not yet been determined what long term effects will result from the addition of low nutrient water into Moses Lake, nor at what rate nutrient concentrations will increase to predilution levels. Nevertheless, substantial improvement in water quality in Parker Horn and the southwestern arm of Moses Lake can probably be expected.

2. Nonpoint sources -

Nonpoint sources, including precipitation, contributed 68.2% of the total phosphorus load to Moses Lake during the sampling year. Rocky Ford Creek contributed 36.5% of the total, Crab Creek and Rocky Coulee Wasteway contributed 15.4% and 12.3%, respectively, and ungaged drainage areas contributed an estimated 3.4% of the total phosphorus load. Welch and Lindell (1977) report that high phosphorus and nitrogen loading to the lake can primarily be attributed to irrigation return flow.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake morphometry data were provided by Wolcott (1965). Tributary flow data were provided by the Washington District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 27.50 km^2.
2. Mean depth: 5.9 meters.
3. Maximum depth: 11.6 meters.
4. Volume: 161.587 x 10^6 m^3.
5. Mean hydraulic retention time: 289 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area (km^2)	Mean flow (m^3/sec)
A-2 Crab Creek	5770.5	2.01
B-1 Rocky Coulee Wasteway	764.0	0.00
D-1 Rocky Ford Creek	1217.3	2.55
Minor tributaries and immediate drainage -	210.7	0.00
Totals	7962.5	4.56

2. Outlet - A-1 Crab Creek 7990.1 6.48

C. Precipitation:

1. Year of sampling: 17.0 cm.
2. Mean annual: 20.0 cm.

III. LAKE WATER QUALITY SUMMARY

Moses Lake was sampled three times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from five stations on the lake and from a number of depths at each station (see maps, pages v, vi). During each visit, depth-integrated samples were collected from each station for chlorophyll *a* analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 2.1 meters at Station 01, 9.1 meters at Station 02, 4.0 meters at Station 03, 6.7 meters at Station 04, and 6.4 meters at Station 05. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll *a* determination are included in III-B. Results of the limiting nutrient study are presented in III-C.

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STORET CODE [illegible]

PHYSICAL AND CHEMICAL CHARACTERISTICS

	([illegible])				([illegible])				([illegible])			
	[illegible]			MAX DEPTH RANGE	[illegible] = 5			MAX DEPTH RANGE	[illegible] = 5			MAX DEPTH RANGE
PARAMETER	N*	RANGE	MEDIAN	(METERS)	N*	RANGE	MEDIAN	(METERS)	N*	RANGE	MEDIAN	(METERS)
TEMPERATURE (DEG CENT)												
0.0-1.5 M DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAX DEPTH**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DISSOLVED OXYGEN (MG/L)												
0.0-1.5 M DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAX DEPTH**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CONDUCTIVITY (UMHOS)												
0.0-1.5 M DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAX DEPTH**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PH (STANDARD UNITS)												
0.0-1.5 M DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAX DEPTH**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL ALKALINITY (MG/L)												
0.0-1.5 M DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAX DEPTH**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL P (MG/L)												
0.0-1.5 M DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAX DEPTH**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DISSOLVED ORTHO P (MG/L)												
0.0-1.5 M DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAX DEPTH**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NO2+NO3 (MG/L)												
0.0-1.5 M DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAX DEPTH**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AMMONIA (MG/L)												
0.0-1.5 M DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAX DEPTH**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
KJELDAHL N (MG/L)												
0.0-1.5 M DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MAX DEPTH**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SECCHI DISC (METERS)	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	

* N = NO. OF SAMPLES
** MAXIMUM DEPTH SAMPLED AT EACH SITE
*** S = NO. OF SITES SAMPLED ON THIS DATE

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/02,03/75	1. *Stephanodiscus*	37,485
	2. *Scenedesmus*	813
	3. *Cryptomonas*	642
	4. *Chroomonas*	428
	5. *Melosira*	342
	Other genera	1,241
	Total	40,951
07/21/75	1. *Aphanizomenon*	5,406
	2. *Oocystis*	2,806
	3. *Scenedesmus*	1,471
	4. *Melosira*	753
	5. *Chroomonas*	479
	Other genera	1,472
	Total	12,387
09/10/75	1. *Aphanizomenon*	7,171
	2. *Oocystis*	850
	3. *Cryptomonas*	702
	4. *Melosira*	481
	5. *Oscillatoria*	444
	Other genera	923
	Total	10,571

2. Chlorophyll _a_

Sampling Date	Station Number	Chlorophyll _a_ (ug/l)
04/02,03/75	01	2.3
	02	1.6
	03	3.3
	04	11.4
	05	7.8
07/21/75	01	46.8
	02	9.3
	03	31.4
	04	31.4
	05	10.3
09/10/75	01	84.6
	02	80.1
	03	82.4
	04	31.2
	05	2.0

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum Yield (mg/l-dry wt.)
a. 04/03/75	Stations 01-03		
Control	0.088	0.296	13.7
0.05 P	0.138	0.296	12.0
0.05 P + 1.0 N	0.138	1.296	36.7
1.00 N	0.088	1.296	32.4
	Stations 04,05		
Control	0.032	0.472	8.9
0.05 P	0.082	0.472	14.5
0.05 P + 1.0 N	0.082	1.472	16.3
1.00 N	0.032	1.472	9.1
b. 09/10/75	Stations 01,02		
Control	0.340	0.370	14.8
0.05 P	0.390	0.370	16.1
0.05 P + 1.0 N	0.390	1.370	43.3
1.00 N	0.340	1.370	41.8
	Stations 03-05		
Control	0.075	0.395	7.7
0.05 P	0.125	0.395	7.0
0.05 P + 1.0 N	0.125	1.395	19.4
1.00 N	0.075	1.395	5.3

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential for primary productivity in Moses Lake was extremely high at both sample collection times (04/03/75, 09/10/75). In the May and September assays for Stations 01 and 02 (the Pelican Horn arm of the lake), a significant increase in yield over that of the control occurred when nitrogen alone was added, indicating nitrogen limitation. Addition of phosphorus alone did not stimulate growth significantly beyond the control yields. It should be noted that the mean orthophosphorus levels at Station 01 were substantially higher than those for the other four lake stations on each sampling date (0.112 mg/l in April, 0.527 mg/l in July, 0.735 mg/l in September). These inflated phosphorus levels, and subsequently the indicated primary limitation by nitrogen in the Pelican Horn arm, probably result from a sewage disposal outfall located directly upstream from lake sampling Station 01 (near Marsh Island).

Algal assay results from Stations 04 and 05 in May indicate primary limitation by phosphorus in the northwestern reaches of Moses Lake during May, but suggest colimitation during fall, when only the simultaneous addition of both phosphorus and nitrogen resulted in an increase in yield over that of the control.

The lake data yield extremely low mean inorganic nitrogen to orthophosphorus (N/P) ratios for Moses Lake during summer and fall (N/P=1), indicating nitrogen limitation in the lake at those times. During spring, the lake data suggest nitrogen limitation at Stations 01 and 02, and primary limitation by phosphorus at Station 03-05. (A mean N/P ratio of 14/1 or greater is generally considered to reflect phosphorus limitation).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Washington National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the maps (pages v,vi), except for the high runoff months of March and April when two samples were collected. Sampling was begun in September 1974, and was completed in August 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Washington District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in kg/km^2/year, in Crab Creek, Rocky Coulee Wasteway, and Rocky Ford Creek at Stations A-2, B-1, and D-1 and multiplying the means by the ZZ area in km^2.

The operator of the Moses Lake wastewater treatment plant provided monthly effluent samples and corresponding flow data.

A. Waste Sources:

1. Known Municipal -

Name	Pop.* Served	Treatment*	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
Moses Lake	12,500	Trickling Filter	3.486	Moses Lake

2. Known Industrial - None

---

*Provided by treatment plant operator.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Crab Creek	4,780	15.3
B-1 Rocky Coulee Wasteway	3,830	12.3
D-1 Rocky Ford Creek	11,070	35.5
b. Minor tributaries and immediate drainage (nonpoint load) -	1,055	3.4
c. Known municipal STP's -		
Moses Lake	9,905	31.8
d. Septic tanks* -	20	0.1
e. Known industrial - None		
f. Direct precipitation** -	485	1.6
Totals	31,145	100.0

2. Outputs - A-1 Crab Creek 17,230

3. Net annual P accumulation - 13,915

---

*Estimate based on 70 lakeshore residences and 1 park.

**Estimated (See NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Crab Creek	95,105	26.6
B-1 Rocky Coulee Wasteway	60,530	16.9
D-1 Rocky Ford Creek	135,975	38.0
b. Minor tributaries and immediate drainage (nonpoint load) -	14,540	4.1
c. Known municipal STP's -		
Moses Lake	21,210	5.9
d. Septic tanks* -	780	0.2
e. Known industrial - None		
f. Direct precipitation** -	29,775	8.3
Totals	357,915	100.0

2. Outputs - A-1 Crab Creek 206,055

3. Net annual N accumulation - 151,860

---

*Estimate based on 70 lakeshore residences and 1 park.

**Estimated (See NES Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Crab Creek	1	16
Rocky Coulee Wasteway	5	79
Rocky Ford Creek	9	112

E. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A "mesotrophic" loading would be considered one between "eutrophic" and "oligotrophic".

Note that Vollenweider's model may not apply to lakes with short hydraulic retention times or in which light penetration is severely restricted by high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Moses Lake	1.13
Vollenweider's "eutrophic" loading	0.54
Vollenweider's "oligotrophic" loading	0.27

V. LITERATURE REVIEWED

Ketelle, Martha J. and Paul D. Uttormark. 1971. Problem Lakes in the United States. U.S. Environmental Protection Agency, Project #16010 EHR. University of Wisconsin, Madison, Wisconsin.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R. A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

Welch, E.B. and L.T. Lindell. 1977. Moses Lake Restoration. Environmental Outlook Vol. 5, No. 5. Institute for Environmental Studies, University of Washington, Seattle, Washington.

Wolcott, E. E. 1965. Lakes of Washington, Volume II. Washington Division of Water Resources, Water Supply Bulletin, 14 and 15.

VI. APPENDICES

APPENDIX A

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR WASHINGTON 11/19/76

LAKE CODE 5306 MOSES LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 7889.2

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
							NORMALIZED FLOWS(CMS)							
5306A1	7889.2	6.54	4.23	4.17	5.41	5.74	3.42	3.54	4.43	7.33	4.76	11.41	7.45	4.68
5306A2	5771.4	1.42	4.32	4.17	2.44	1.17	1.28	1.35	1.46	1.63	1.35	0.46	0.90	2.01
5306B1	744.3	0.3	0.2	1.3	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.0	1.2	0.0
5306C1	1217.3	2.04	1.49	1.71	2.41	2.39	2.83	2.76	2.90	2.43	2.66	3.46	2.27	2.59
5306ZZ	779.3	0.3	0.3	0.3	0.3	0.7	0.3	0.3	0.3	0.4	0.3	0.0	0.2	0.0

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 7889.2 TOTAL FLOW IN = 54.79
SUM OF SUB-DRAINAGE AREAS = 7889.2 TOTAL FLOW OUT = 77.79

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
5306A1	9	74	8.855	20	8.750				
	10	74	9.911						
	11	74	15.406	2	11.072				
	12	74	16.251	4	12.912				
	1	75	9.231	16	9.005	19	9.231		
	2	75	12.290	5	11.270	16	12.629		
	3	75	13.346	1	13.194				
	4	75	15.241	7	14.157	27	15.971		
	5	75	7.787	4	15.716				
	6	75	6.088						
	7	75	6.598	1	7.023				
	8	75	9.486	13	9.119				
5306A2	9	74	3.511	20	3.455				
	10	74	3.115						
	11	74	1.840						
	12	74	1.161	8	1.303				
	1	75	0.821	16	0.736	19	1.765		
	2	75	0.765	5	0.651	16	0.765		
	3	75	5.720	1	1.218				
	4	75	7.306	3	4.212	27	6.513		
	5	75	4.966	19	3.048				
	6	75	2.215						
	7	75	2.520	1	2.209				
	8	75	2.846	13	2.480				

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[illegible]	MONTH	[illegible]	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
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	10	[illegible]	[illegible]						
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	12	[illegible]	[illegible]	[illegible]	[illegible]				
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	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
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[illegible]	9	[illegible]	[illegible]	[illegible]	[illegible]				
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APPENDIX C

PHYSICAL AND CHEMICAL DATA

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                        00010     00300     00077     00094     00400     00410     00610     00625     00630     00671
 DATE    TIME DEPTH    WATER       DO      TRANSP    CNDUCTVY     PH      T ALK     NH3-N    TOT KJEL   NO2&NO3  PHOS-DIS
 FROM     OF           TEMP                SECCHI    FIELD                CACO3     TOTAL       N       N-TOTAL   ORTHO
  TO     DAY  FEET     CENT      MG/L      INCHES    MICROMHO     SU      MG/L      MG/L      MG/L      MG/L     MG/L P

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                       00665     32217     00031
 DATE    TIME DEPTH   PHOS-TOT  CHLRPHYL  INCDT LT
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  TO     DAY  FEET    MG/L P     UG/L     PERCENT

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APPENDIX D

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 76/11/15
NAT'L EUTROPHICATION SURVEY
EPA- LAS VEGAS

530981
47 05 00.0 119 20 00.0 4
CRAB CREEK
53 7.5 MOSES LAKE S
T/MOSES LAKE 170991
BNK 50 FT E SEC RD BRDG 1.4 M S WESTLAKE
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/09/20	13 00		0.040	1.400	0.045	0.135	0.210
74/12/08	12 30		1.306	0.750	0.070	0.030	0.075
75/01/26	17 00		0.232	0.400	0.112	0.027	0.030
75/01/29	09 45		0.256	0.450	0.024	0.026	0.025
75/02/05	15 30		0.286	0.400	0.072	0.024	0.040
75/02/26	12 35		1.432	1.700	0.040	0.040	0.050
75/03/03	14 40		0.352	0.400	0.090	0.044	0.090
75/03/30	17 15		0.390	0.700	0.055	0.040	0.090
75/04/02	19 45		0.086	1.000	0.090	0.025	0.080
75/04/27	12 50		0.240	0.400	0.075	0.045	0.080
75/05/05	19 00		0.040	0.450	0.050	0.055	0.090
75/07/01	20 30		0.070	1.200	0.070	0.085	0.140
75/08/13	20 00		0.085	1.050	0.025	0.025	0.090

K VALUE KNOWN TO BE LESS
THAN INDICATED

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STORET RETRIEVAL DATE 76/11/09
NAT'L EUTROPHICATION SURVEY
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                                                                       CRAB CREEK
                                                                       53      7.5 MOSES LAKE N
                                                                       T/MOSES LAKE              170491
                                                                       SCHOPP ROAD XNG 4.5 MI NE OF MOSES LAKE
                                                                       11EPALES            2111204
                                                                        0000 FEET  DEPTH  CLASS 00

                              00630      00625      00610      00671      00665
  DATE    TIME DEPTH NO2&NO3   TOT KJEL   NH3-N    PHOS-DIS   PHOS-TOT
  FROM    OF         N-TOTAL      N       TOTAL     ORTHO
   TO     DAY  FEET   MG/L      MG/L      MG/L     MG/L P     MG/L P

[illegible] 10 30         1.440      0.420     0.027      0.015      0.037
[illegible] 11 45         1.270      1.000     0.060      0.050      0.060
[illegible] 14 15         1.380      0.480     0.056      0.050      0.070
[illegible] 10 20         1.240      0.600     0.080      0.064      0.070
[illegible] 14 50         1.290      0.560     0.084      0.056      0.080
[illegible] 13 20         1.010      1.100     0.096      0.074      0.080
[illegible] 15 25         0.440      0.400     0.024      0.044      0.090
[illegible] 10 15         1.050      1.100     0.100      0.125      0.220
[illegible] 10 05         0.900      1.150     0.037      0.105      0.205
[illegible] 13 35                    1.150     0.040      0.035      0.140
[illegible] 25 00         1.150      0.675     0.135      0.095      0.115
[illegible] 10 45         0.740      0.450     0.095      0.020      0.040
[illegible] 10 50         1.770      0.600     0.025      0.031      0.040
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STORET RETRIEVAL DATE 76/11/16                                    530001
NAT EUTROPHICATION SURVEY                                        47 08 45.0 119 15 28.0 4
EPA-LAS VEGAS                                                    GRIZZLY COULEE WATERWAY
                                                                 53      7.5 MOSES LAKE W
                                                                 T/MOSES LAKE            130941
                                                                 BRIDGE ON BROADWAY AVE 1.8 M NE JCT HWY 11
                                                                 11EPALES              2111204
                                                                  0000 FEET  DEPTH  CLASS 00

                                 00630      00625      00610      00671      00665
  DATE    TIME DEPTH  NO2&NO3    TOT KJEL   NH3-N      PHOS-DIS   PHOS-TOT
  FROM     OF         N-TOTAL    N          TOTAL      ORTHO
   TO     DAY  FEET   MG/L       MG/L       MG/L       MG/L P     MG/L P

74/09/12 11 27          1.400      0.250      0.025      0.008      0.095
74/12/08 11 55          1.700      0.300      0.070      0.130      0.110
75/01/14 10 50          1.700      0.700      0.176      0.120      0.140
75/01/28 10 05          1.700      0.500      0.066      0.080      0.100
75/02/05 14 30          1.200      0.300      0.066      0.090      0.112
75/02/24 13 45          1.700      0.700      0.112      0.147      0.200
75/03/13 15 35          1.700      0.350      0.016      0.120      0.130
75/03/14 17 25          1.500      0.300      0.025      0.095      0.080
75/04/02 17 50          1.400      0.300      0.025      0.150      0.190
75/04/27 13 30          0.800      0.500      0.045      0.076      0.153
75/05/30                1.440      1.250      0.075      0.035      0.070
75/07/02 16 05          1.300      0.350      0.040      0.075      0.150
75/08/13 19 50          1.450      0.400      0.025      0.065      0.080
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STORET RETRIEVAL DATE 76/11/29
NATL EUTROPHICATION SURVEY
EPA- LAS VEGAS

530401
40 15 42.0 119 27 18.0 4
[illegible] FORD CREEK
47 7.5 GRANT [illegible]
TAMARES LAKE
[illegible]
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/09/27	17 00		1.290	0.250	0.[illegible]75	0.095	0.122
74/12/08	11 13		1.344	0.289	0.[illegible]45	0.130	0.150
75/01/25	10 15		1.320	0.500	0.090	0.120	0.150
75/01/29	12 00		1.320	0.300	0.032	0.120	0.120
75/02/05	17 30		1.720	0.200	0.041	0.120	0.170
75/02/16	14 00		1.290	1.400	0.104	0.104	0.130
75/03/07	11 20		1.720	0.400	0.072	0.244	0.176
75/03/18	16 40		1.300	0.450	0.076	0.170	0.150
75/04/07	19 30		1.240	0.225	0.035	0.105	0.130
75/04/27	14 15		1.280	0.475	0.078	0.114	0.152
75/05/30	19 30		1.250	0.350	0.095	0.105	0.130
75/07/01	18 00		1.240	0.350	0.078	0.095	0.120
75/08/13	18 29		1.300	0.350	0.025	0.195	0.160

STORET RETRIEVAL DATE [illegible]
NAT'L EUTROPHICATION SURVEY
EPA-LAS VEGAS

[illegible]
[illegible]
[illegible] LAKE
[illegible]
[illegible] LAKE
[illegible] LAKE
11EPALES [illegible]
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] [illegible]									
[illegible] CP(T)- [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1975

STATE OF WASHINGTON

Mean or median values for six of the key parameters evaluated in establishing the trophic conditions of Washington lakes sampled are presented to allow direct comparison of the ranking, by parameter, of each lake relative to the others. Median total phosphorus, median inorganic nitrogen and median dissolved orthophosphorus levels are expressed in mg/l. Chlorophyll a values are expressed in ug/l. To maintain consistent rank order with the preceding parameters, the mean Secchi disc depth, in inches, is subtracted from 500. Similarly, minimum dissolved oxygen values are subtracted from 15 to create table entries.

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P
5301	AMERICAN LAKE	0.027	0.175	343.000	4.622	15.000	0.007
5302	BANKS LAKE	0.021	0.040	394.533	7.373	10.000	0.007
5303	CHELAN LAKE	0.005	0.070	111.400	0.405	6.400	0.003
5304	DIAMOND LAKE	0.014	0.060	383.667	14.537	14.200	0.010
5305	GREEN LAKE	0.027	0.050	415.000	2.965	11.400	0.009
5306	KEECHELUS LAKE	0.007	0.040	280.250	1.400	9.200	0.002
5307	MAYFIELD LAKE	0.014	0.155	462.000	4.250	10.400	0.007
5308	MEDICAL LAKE	0.275	0.225	441.714	16.425	15.000	0.146
5309	MOSES LAKE	0.115	0.150	463.600	29.060	14.600	0.030
5310	OFFUTT LAKE	0.010	0.110	463.333	1.225	7.200	0.009
5311	SAMMAMISH LAKE	0.015	0.210	374.070	7.290	14.600	0.024
5312	WHATCOM LAKE	0.009	0.320	290.000	3.422	10.400	0.009
5313	LOWER GRANITE RESERVOIR	0.033	0.150	435.500	4.075	7.200	0.022

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
5301	AMERICAN LAKE	29 (3)	50 (6)	67 (8)	50 (6)	4 (0)	58 (7)
5302	BANKS LAKE	42 (5)	100 (12)	58 (7)	25 (3)	46 (5)	71 (8)
5303	CHELAN LAKE	100 (12)	67 (8)	100 (12)	100 (12)	100 (12)	92 (11)
5304	DIAMOND LAKE	63 (7)	75 (9)	75 (9)	17 (2)	33 (4)	25 (3)
5305	GREEN LAKE	29 (3)	83 (10)	17 (2)	75 (9)	63 (7)	46 (5)
5306	KEECHELUS LAKE	92 (11)	92 (11)	92 (11)	83 (10)	75 (9)	100 (12)
5307	MAYFIELD LAKE	63 (7)	58 (7)	33 (4)	58 (7)	63 (7)	71 (8)
5308	MEDICAL LAKE	0 (0)	8 (1)	42 (5)	8 (1)	4 (0)	0 (0)
5309	MOSES LAKE	8 (1)	29 (3)	0 (0)	0 (0)	21 (2)	8 (1)
5310	OZETTE LAKE	75 (9)	42 (5)	25 (3)	92 (11)	88 (10)	33 (4)
5311	SAMMAMISH LAKE	50 (6)	17 (2)	50 (6)	33 (4)	21 (2)	83 (10)
5312	WHATCOM LAKE	83 (10)	0 (0)	83 (10)	67 (8)	46 (5)	46 (5)
5313	LOWER GRANITE RESERVOIR	17 (2)	25 (3)	8 (1)	42 (5)	88 (10)	17 (2)